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EFFECTS OF VARYING VISUAL DISPLAY CHARACTERISTICS OF THE T-4G, A T-37 FLIGHT SIMULATOR

By

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Two experiments were conducted using the T-4G, a T-37 flight simulator, to investigate the benefit to simulation of visual displays which have color or are collimated. Thirty-two Air Force undergraduate pilots learned approach and landing in the T-4G using either black and white or colored imagery. Thirty-eight instructor pilots performed approach and landing with visual displays that had collimation or reduced collimation. No statistically significant differences were found in either experiment. Power analysis shows that each of these experiments would have detected a practically significant difference, if one existed, with a probability of more than .75. There are no psychophysical reasons to use either color or collimation. User acceptance is another thing, and if color and collimation improve acceptance, they should be used.

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SUMMARY

Objectives

Two experiments were conducted with the T-4G, a flight simulator having the cockpit configuration of a T-37 aircraft. The first experiment investigated the effect on pilot performance of using colored imagery as opposed to black-and-white imagery in the visual display. The second experiment compared display collimation with reduced collimation. Collimation causes the displayed image to appear to be an infinite distance away. An image which is not collimated appears at the surface of the cathode ray tube (CRT) faceplate. Reduced collimation places the image at an intermediate position. Because of equipment limitations, these studies are not elaborate, but they do address problems which have been scantily treated in the past.

Approach

The T-4G simulator has a T-37 cockpit equipped with a single window (44x28 degrees) visual display system. The visual scene is generated from a 35mm color film of an approach to a landing at an airport; a flying spot scanner is used to generate a visual scene which corresponds to pilot-induced deviations from the filmed flightpath. Filmed approaches and landings were available for two airports. One approach was to Williams AFB, Arizona, where the scenery is desert country; the other approach was to O'Hare Airport, Chicago, Illinois; this film is more colorful. Approaches to both airports were used in the color study to insure the color effect, if any, would not be missed. Color and black-and-white scenes were displayed using the same CRT. For collimated scenes, a smaller black and white CRT was used. This CRT permitted a great reduction in collimation although collimation could not be completely eliminated; the size of the scene displayed was necessarily reduced along with the reduction in collimation.

Specifics

Color Study. Thirty-two Air Force undergraduate student pilots were trained in approach and landing in the T-4G. Each student performed an approach and landing 35 times. Instructor pilots (IPs) gave the students conventional instruction on all trials except the last four; these four were the criterion trials on which the students' performances were rated by the IPs. The training trials were accomplished with either a black and white or a color display using imagery of either Williams AFB or O'Hare International Airport.

Collimation Study. Thirty-eight IPs at Williams AFB were subjects in this study. Student pilots were not used because mechanical reliability problems with the T-4G would not permit the precise scheduling students require. The task was again approach and landing in the T-4G. After three practice trials, each IP performed five approach and landings on which performance was rated by a research IP. Half of the IPs used the collimated display; the remainder used a display with reduced collimation. Only black-and-white imagery from Williams AFB was used in the collimation study.

The ratings received on their last four trials by students in the Color Study were analyzed by analysis of variance (ANOVA) and the Mann-Whitney U-test. The rates at which the groups learned were analyzed by trend ANOVA. No difference was found in either the learning rates or the final performance. That is, there was no significant difference between black and white and color in learning rates or final performance, or between Williams AFB and O'Hare on final performance only; learning rates between the two airfields were not analyzed. Also, no differences were found in the Collimation Study. Neither ANOVA nor a Mann-Whitney U-test of the ratings the IPs received in their five trials showed a significant difference between display conditions of collimation and reduced collimation. Power analysis shows that each of these experiments would have detected a practically significant difference, if one existed, with a probability of more than .75.

Conclusions

Color Study. Popular opinion favors the use of color; it is felt that color improves performance. There are no psychophysical reasons why color should improve performance except for color stereoscopy. In the

absence of depth cues, equidistant red and blue objects appear to be at different distances. This phenomenon may improve depth perception by enhancing perceived texture. Research pertinent to this question does not show conclusively that color in a simulator visual display is associated with better performance than black and white.

Collimation Study. Popular opinion also favors the use of collimation. Users say collimation increases realism and aids depth perception. Accommodation and convergence are effective when objects viewed are at different distances. Collimation puts all objects the same distance away. Stereopsis depends on binocular vision, but a visual display provides only monocular information since it is a single picture (not a different picture for each eye). Collimation does not provide depth cues from accommodation, convergence, or stereopsis. Collimation does produce a sense of volume which lends a realistic feeling. Research, however, does not show that collimation of a simulator visual display is associated with better performance than is reduced collimation.

Implications. Limitations of the equipment used in this study restrict application of the results obtained to single window, narrow angle displays and in the case of the second experiment, to reduced collimation rather than complete decollimation. The results show no difference in the ability of pilots to make a simulated approach and landing when using a colored versus a black and white or a collimated versus a reduced-collimation visual display. These results suggest that color in a simulator visual display is not necessary and that the benefit of collimation is questionable. However both color and collimation may influence user acceptance, and if this is a factor in simulator utilization and effectiveness then color and collimation should be used.

PREFACE

This effort was conducted at the Flying Training Division of the Air Force Human Resources Laboratory, Williams Air Force Base, Arizona, and supported by the 82nd Flying Training Wing, Williams Air Force Base. The study was in support of project 1123, Flying Training Development; task 112303, Exploitation of Flight Simulation in Undergraduate Pilot Training. Mr. Jim Smith was project scientist; Mr. Robert Woodruff was principal investigator.

Appreciation is extended to the people who contributed to the conduct of this project: Capt Tom Biel, Capt Ed Chun, Capt Tom Conley, Mr. Tom Farnan, Capt James Freed, Capt John Fuller, Capt Robert Hey, Mr. William Hopkins, Capt James Keller, Mr. Paul Kubiak, Capt Lee Lesher, Capt John Lindsay, Maj Jay Paulsen, and all the students and instructor pilots who served as subjects.

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I. INTRODUCTION

The T-4G is a T-37 flight simulator which has 2 1/2 degrees (pitch, roll, and heave) of platform motion freedom and a visual display consisting of a single 25 inch color cathode ray tube (CRT) and collimating mirror. The field of view is 44° horizontal and 28° vertical. When it was first acquired in 1972, the T-4G was used in a series of studies to demonstrate the benefits of simulation to the Air Force undergraduate pilot flight training syllabus. Shortly after the completion of those studies, the Advanced Simulator for Pilot Training (ASPT) was acquired, and the research efforts were concentrated on that device. However, the T-4G permitted research possibilities beyond those which could be accomplished using ASPT: specifically, studies of the effect of color versus monochromatic visual displays and collimated versus reduced-collimated displays on the learning and performance of landing. A comparison of color versus monochromatic displays was completed in 1975 and the intention was to continue immediately with a comparison of collimation and reduced collimation. But the T-4G began to fail repeatedly. Data collection for the collimation study was attempted and abandoned four times. Finally in November of 1977, data collection was successfully completed on a reduced experimental design. Due to the limitations of the T-4G, these studies are not elaborate, but they do address problems which have been scantily treated in the past and which have never been addressed in an operational training environment.

II. COLOR STUDY

Introduction

Contemporary popular opinion favors using color in flight simulator visual displays; nearly all operationally-used flight simulators purchased within the past 15 years have color visual displays. The reason for this demand for color seems to be user acceptance; pilots have the opinion that display color adds realism which improves performance and training value. The opinion has been expressed that color aids depth perception. But the real question is whether color has enough training value to justify the added complexity and expense it entails. There is very little empirical evidence to support the superiority of color displays over monochrome systems for training devices.

There is some evidence that display color may be valuable for target detection or where coding is involved (Christ & Teichner, 1973; DeMars, 1975; Fowler & Jones, 1972; Whitehurst, 1975; Williams, 1965. Even so, Puig's (1976) conclusion after reviewing most of this literature was, ". . . it is doubtful whether presenting the observer with a realistic color picture of the scene is particularly advantageous in most air-to-ground operations." Furthermore, most flight simulators having visual displays are used primarily to train and practice takeoff and landing where coding and target detection are not particularly important.

The phenomenon of color stereoscopy may provide some basis for using color. Equidistant red and blue objects, in the absence of depth cues, appear to be at different distances. Helson (1958, p. 263) has suggested that this aids organization of the visual field by enhancing the perception of texture. Brown and Herrnstein (1975) state, "The perception of color is yet another way we give solidity to the world around us. . . . Objects that blend into each other in black and white spring apart when seen in color" (p. 396). In this way, color would probably enhance depth perception (and improve performance) if the size of the objects being viewed were known (e.g., the size of trees).

The only research addressing the potential advantages of color displays to takeoff and landing performance is that of Chase (1970, 1971). He compared the performance of seven qualified pilots landing a DC-8 simulator with and without color in the visual display (a model/probe system). This was a complicated factorial study that involved the use of projected and monitor displays and two variations of the task: (a) a visual approach and landing with no instruments except the airspeed and the altimeter and (b) an approach and landing with a complete instrument complement. On the visual task, Chase measured several parameters, such as longitudinal flight path alignment, lateral flight path alignment, dispersion of touchdown point, and touchdown rate of descent. He generally found no statistically significant differences between color and black and white except on touchdown dispersion ($p < .05$). He concludes,

> The experimental results obtained from the performance measure differences, although small, are identifiable. Comparison of the effects of color and black and white by these differences showed that touchdown distance and standard deviation increased for both the color monitor and color projector displays; however, for the same performance obtained with the color monitor, the agreement was more favorable with the actual flight data. The performance for rate of descent at touchdown was also lower for color, particularly with the monitor display, but still higher than for actual flight (1970).

The purpose of the present study was to take advantage of the T-4G's color capacity to gain understanding about the contribution of display color to the training of Air Force undergraduate pilots.

Method

The equipment used in this study was the T-4G simulator. Appendix A gives a more complete description of the T-4G. In order to produce the black-and-white condition for this experiment, the power to the color circuitry for the display was turned off. Prior to the experiment, instructor pilots optimized the black and white and color displays by adjusting the brightness, contrast, and color saturation. The settings agreed upon were not altered during the experiment.

The subjects were 32 male Air Force undergraduate pilot training (UPT) students. These students served in the experiment at a point immediately prior to their T-37 flight training. They all were graduates of the Air Force Academy and were assigned to Williams AFB. Each student had completed 15 hours of training in the Cessna 172, which is prerequisite to T-37 training, and had been given instruction for familiarization with the T-37 cockpit and flying characteristics.

The task the students performed was to fly a straight-in approach from 2 miles out and to land on the runway. An instructor pilot (IP) accompanied each student in the T-4G during experimental sessions. The IP provided the student with conventional instruction in the task except that IPs were asked to limit their demonstrations of technique to two. All the usual T-37 instruments were available to the students, except the instrument landing system (ILS) display. This instrument was concealed to increase the student's dependence on the visual display. Half of the students learned to land with a color display and half learned without color. Two approach and landing environments were used: Williams AFB and O'Hare Airport in Chicago. The Chicago area is more colorful compared to the desert environment of Williams AFB, and it was thought that color cues at O'Hare might reveal a difference between black and white and color that could be missed at Williams AFB. Thus, there were four treatment conditions: color and black-and-white presentations of both O'Hare and Williams AFB. Eight different students participated in each of the four treatment conditions.

Four IPs instructed in the T-4G, and each trained eight students; two in each of the four treatment conditions. The IPs were all highly experienced, having served from 25 to 38 months as IPs at Williams AFB.

Each subject reveived 35 trials in the T-4G during a single experimental session approximately 1 hour long. Selection of 35 trials was based on previous T-4G experience which indicated that between 30 and 35 trials were sufficient for a student to learn to land the T-4G proficiently (Woodruff & Smith, 1974).

The dependent variable was the level of performance achieved by the student pilots after 31 training trials. Evaluation was accomplished, as it is in actual UPT, by IP rating but with one modification. Whereas in regular training, the IPs use a four-point scale to rate their students, in this study, these four points were expanded to 12 points. Trials 32 through 35 were criterion trials. A student's final proficiency was considered to be the average rating of these four trials. Ratings were also assigned on trials 2, 12, and 22 also to reveal learning rates. The process of rating assignment by the IPs was slightly complicated by the fact that in the T-4G, the IP cannot see the exact visual scene which the student observes; the display optics are located at the student position. However, the IP does have all the normal flight instruments to watch and, in addition, is provided with a 9-inch CRT repeater of the student's display. This repeater is located at the IP's eye-level and about 10° to the right. Previous experience with the T-4G has shown that this arrangement is satisfactory not only for the IPs to rate student performance, but also to fly and to instruct (Woodruff & Smith, 1974).

Results

An analysis of variance (ANOVA) of the student's final proficiency scores did not reveal a significant difference between the four treatments (color or black and white, and Williams AFB or O'Hare). A Mann-Whitney U test did not show a significant difference between the color and black-and-white conditions (U=126). The mean for color was 9.46 and that for black and white was 9.56. Table 1 summarizes the ANOVA.

Table 1. **Color Study**

Source	SS	df	MS	F
Chromaticity (C)	0.08	1	0.08	–
Airfield (A)	0.31	1	0.31	–
AC	0.83	1	0.83	–
Error	148.68	28	5.31	
Total	149.90	31		

Figure 1 shows learning curves for the two chromaticity conditions. These curves are based on data taken in trials 2, 12, and 22 and the criterion trials. Inspection of these curves shows them to be typical learning curves with no apparent differences in the two conditions; however, the curves show that the criterion trials used in the analysis did not occur until learning was at asymptote. For this reason, it was thought to be desirable to examine the two conditions by trend ANOVA to confirm that no difference was masked by overlearning. No difference was found. Table 2 summarizes this analysis.

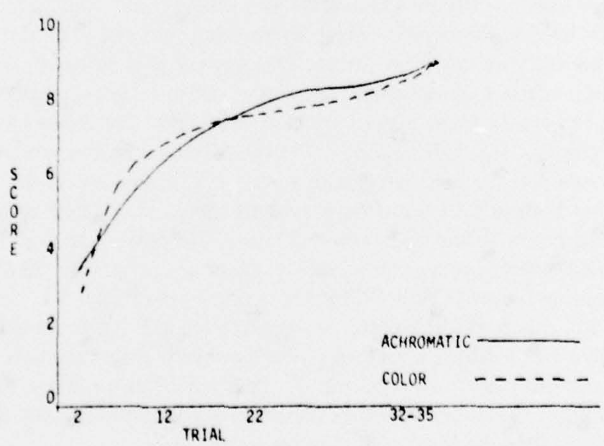

Figure 1. **Learning curves.**

Table 2. **Trend ANOVA for Chromaticity**

Source	SS	df	MS	F
A: Chromaticity	1.68	1	1.68	—
Error (a)	333.49	30	11.12	
B: Trials	922.75	6	153.79	105.34*
A X B: Chromaticity X Trials	2.70	6	0.45	—
Error (b)	262.03	180	1.46	

*$p < .001$.

Since the condition of no training performance difference between black and white and color was of primary interest in this study, some statement should be made to support a conclusion that no difference exists between them, or more particularly that color is not better than black and white. The best way to do this appears to be by power analysis (Cohen, 1977). The probability, according to Cohen, is .72 that if the mean performance of the color group did exceed that of the black-and-white group on the criterion trials by a "large" (practically significant) difference, this experiment would have detected it at the $p=.05$ level; consequently, a judgment that no differences exist between the two conditions should be entertained.

Discussion

Except for color stereoscopy, there are no psychophysical reasons to support the use of color in simulator visual displays (unless coding or target detection in involved). Proponents of the use of display color say that it adds realism and is a cue for depth perception. Perhaps color stereoscopy does aid depth perception, but research has not conclusively demonstrated that display color improves performance. However, color displays seem to be more likely to gain user acceptance than black-and-white displays. If user acceptance is a crucial factor in simulator utilization and effectiveness, the use of color may be supported on that basis.

III. COLLIMATION STUDY

Introduction

As with display color, contemporary opinion also favors using collimation in flight simulator visual displays. Simulator users say that collimation, like color, increases display realism and aids depth perception. The devices used to achieve collimation are a heavy and expensive part of simulator visual display systems. It may be that the benefits which derive from collimation do not justify its use. There is a theoretical reason to suspect that this might be so. The primary cues to depth are a function of binocular vision. These are accommodation, convergence, and stereopsis (or retinal disparity). Accommodation is the bending of the lens in the eye to focus rays of light on the retina. The closer an object is to a viewer, the more the lens must accommodate. This action by the lens is sensed and experience enables the amount of muscle strain that is sensed to be associated with distance. Convergence is the rotation of the eyeballs toward an object so that the optical axes of both eyes are aimed at it. Once again muscle strain indicates distance. If an object is further away than about 50 feet, the optical axes of the two eyes are parallel because the rays of light which come from a distant object are essentially parallel. A collimated display makes rays of light from an object (e.g., a CRT) that is much closer than 50 feet to a viewer appear to be parallel (in columns), and this causes the object to be perceived as if it were at a distance. Stereopsis refers to the fact that each eye sees a different picture of nearby objects since they have different points-of-view. The internal (central nervous system) integration of these two pictures into a single perception provides information about distance; the more different (disparate) the pictures are, the closer the object is. If an object is at a comparatively long distance, both pictures are the same.

The typical collimated simulator display does not provide accommodation, convergence, or stereopsis distance cues. All displayed objects are perceived by accommodation, convergence, and stereopsis as if they were at a distance. This is true even of a refueling boom which practically comes though the windshield. (In such a case, the pilot would know the true position of the boom because of a familiarity with its size, etc.) The reasons for this are that, first, all the objects displayed are in the same image plane, which is perceived by accommodation and convergence to be a long way off because rays of light coming from it are parallel. Second, when objects are at a distance, both eyes see the same picture, and a single picture is all that is seen in a typical simulator display. Thus, objects it displays are also interpreted to be at a distance by stereopsis.

In spite of these limitations, collimation does two things which enhance realism. First, it provides a feeling of volume; the display does appear to be a long way off, and when the pilot moves his head, objects in the display appear to move relative to items in the cockpit (e.g., the canopy rail). Second, collimation makes it necessary for the pilot's eyes to be focused to infinity on the display after they have been focused on a nearby object, such as the instrument panel, just as in the real world.

Matheny, Lowes, Baker, and Bynum (1971) suggest that "... the argument that the majority of the visual cues of importance to the pilot are those which are at a distance sufficient to make them monocular...." (p. 20), may not be correct "...particularly with respect to the ground plane on which viewed objects rest since this ground plane presumably extends from immediately below the individual to infinity at the horizon. Consequently, it is postulated that near points on the ground plane should not always appear at infinity" (p. 21). They further state that "Evidence with respect to the advantages of such a system (i.e. collimated display) either in terms of more closely approximating the real world visual cues or as a contributing parameter to training devices is not available" (p. 20). They suggest that "...the comparative effectiveness of using virtual imagery as opposed to flat plane, two-dimensional projections for distance viewing should be investigated with flat planes positioned at near (less than five ft.) and far (greater than 20 ft.) distances" (p. 21). They then conclude, "It is the hypothesis of these investigators that the differences would not be significant or practical..." (p. 21).

Only three studies have been found which address this problem but none of these suggest a resolution. Brown (1970) found no differences in the touchdown performances of four pilots when viewing a CRT image at 2 feet and an image at 6 feet created by a lens system. In the study cited previously, Chase (1970, 1971) included comparison of a projected and a "quasi-collimated" image on a monitor. The projected image appeared 10 feet in front of the pilot. The "quasi-collimated" image was at 10.88 feet (the collimating lens did not completely collimate the displayed image). He says,

> The pilots were able to execute better performance in minimizing the time outside the glide slope error limits with the monitor display compared to the projector display. However, for the lateral localizer performance, the error was smaller for the projector display than for the monitor display (1970).

He further says,

> [The pilots] comments were more favorable toward the monitor display, because of better picture quality and depth perception than was evident in the projector display (1970).

It should be noted that these differences did not result from differences in image distance. Barrett, Kobayash, and Fox (1968) had 14 subjects using a projected image display and 10 subjects using a virtual image display operate an automobile simulator. Their task was to produce a requested speed with only external visual cues. Image distances were not reported. Barrett et al. conclude, "The results clearly indicate that the projected and virtual image displays did not differentially affect speed judgments."

The purpose of this study was to take advantage of the simple optical system of the T-4G to gain some indication about the importance of visual display collimation to pilot performance.

Method

In order to provide experimental conditions of both collimation and reduced collimation, it was necessary to make some changes to the T-4G display system. The basic change was to use a 17-inch CRT instead of the 25-inch CRT originally in the T-4G. The smaller diameter of the 17-inch CRT made it possible to move it 2.7 inches toward the collimating mirror. The original position of the CRT was at the focus of the collimating mirror. When the CRT is at the focus of the mirror, the pilot sees a collimated display; the picture on the CRT is seen as a flat image an infinite distance away. Moving the CRT closer to the mirror causes the flat image to move toward the pilot. A movement of 2.7 inches brings the image to 15 feet behind the surface of the mirror. The T-4G pilot sits about 4 feet from the mirror, so in the reduced-collimation condition the image appears to be about 19 feet away. Physical constraints of the system did not permit moving the CRT enough to produce a truly uncollimated condition.

The use of a 17-inch rather than a 25-inch CRT changed the field of view of the collimated display from 44° x 28° to 40° x 32°. The aspect ratio of the 17-inch CRT is different from that of the 25-inch CRT, resulting in a display with reduced width but increased height. In the reduced-collimation condition, the field of view was 34° x 27°. The width of the Electronic Perspective Transformation (EPT) system (see Appendix A) image was widened to compensate for the reduced width of the display in the reduced-collimation condition. Experienced pilots optimized the two display conditions before data collection, and the displays were judged to be equivalent in spite of the difference in field of view.

Both the collimated and reduced-collimation displays were black and white because the EPT electronics did not generate enough power to drive the color circuitry of the 17-inch monitor (a Sony Trinatron).

The subjects were 20 T-37 and 18 T-38 male instructor pilots (IPs) from Williams AFB. IPs were used for this study because the uncertainty of T-4G reliability did not permit the precise scheduling the UPT students require. Ten T-37 and nine T-38 IPs flew the T-4G in each treatment condition.

The task, as in the Color Study was to fly a straight-in approach from 2 miles out and land on the runway. Learning was not a consideration in this study. All of the subjects, including those who then were T-38 pilots, were familiar with landing the T-37. A brief introduction to the T-4G, a demonstration and three practice trials of the task were all the preparation the IPs required. As before, the ILS display was concealed to increase the pilot's dependence on the visual display. Only the Williams AFB imagery was used for this study.

After practice, each pilot flew five approach and landing sequences and received a performance rating on each attempt from a research IP who accompanied him. The pilot's final score was the average of the five ratings.

Results

An analysis of variance of the IPs' proficiency scores did not reveal a significant difference between the two treatments. The mean for the group using collimation was 86.6; for the group with reduced collimation, the mean was 88.1. Table 3 summarizes the ANOVA. Analysis by the Mann-Whitney U test was also not significant (U=158.5).

Table 3. **Collimation Study**

Source	SS	df	MS	F
Display	20.63	1	20.63	0.137
Error	5,426.21	36	150.73	
Total	5,446.84	37		

Analysis by Cohen's technique of power analysis shows that this experiment would have detected a "large" difference at the $p=.05$ level (one-tail) with a probability of .78. Thus a judgment should be entertained that display collimation does not contribute to better pilot performance in a simulator than reduced collimation.

Discussion

The considerations mentioned in Section I of this report suggest that display collimation is not a necessary parameter of simulator visual display systems. This indication has also been supported by the present study. If collimation were to be omitted from simulator systems, a great deal of money and complexity could be saved. However, none of the work cited or this study can be considered conclusive. A conclusive study would carefully control collimation and non-collimation as suggested by Matheny et al. (1971) (image distance greater than 20 feet and less than 5 feet). Other display parameters should also be controlled: These would include field of view, resolution and brightness.

A decision to omit collimation must be based on convincing evidence. As in the case of color, collimation is generally favored by users who say it greatly increases realism and improves performance. If user acceptance depends heavily on the use of collimation, consideration should be given to using it even if there is no contribution to performance.

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APPENDIX A: A/F37A-T4G DESCRIPTION

The T-4G is an updated ME-1 trainer modified to accommodate a Singer SPD Electronic Perspective Transformation (EPT) visual system. The ME-1 itself is essentially a T-4 instrument trainer mounted on a two-degrees-of-freedom motion base. Figure A1 is an artist's concept of the T-4G.

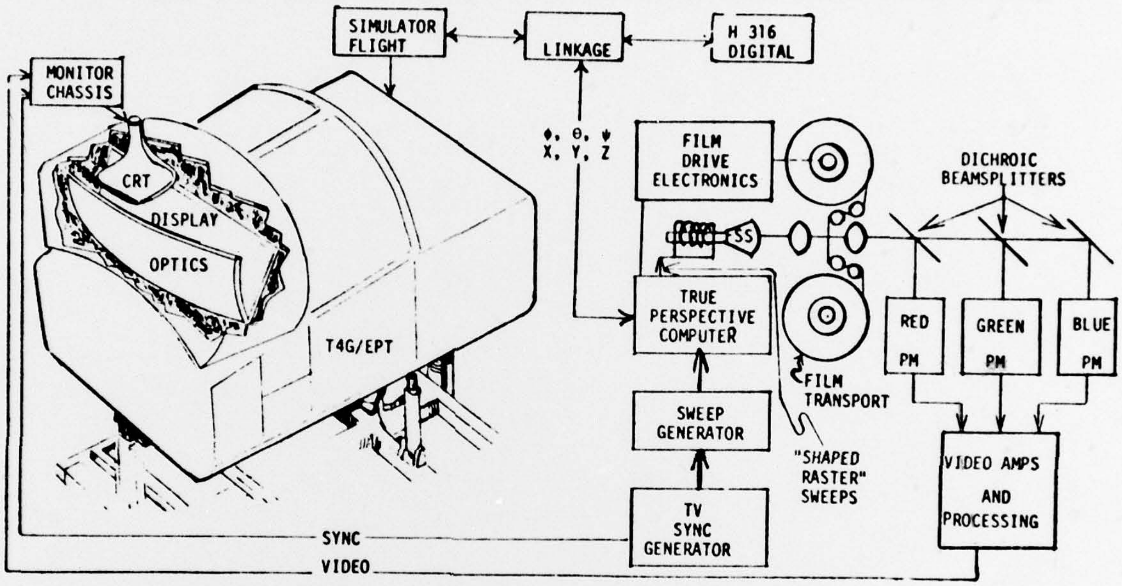

Figure A1. **Artist's concept of the T-4G.**

Following is a list of the major simulator components:

- Modern Microelectronic Computer
- T-4 Cockpit
- Two-Degrees-of-Freedom Motion
- EPT Visual System
- External Operator Station
- Internal Instructor Station

The motion system moves ± 5.5° pitch, ± 8.5° in bank, and vertically +6 inches and –4 inches. The visual display field of view is 44° x 28°, and the image is provided in full color at infinity. Image generation for the visual display is obtained from two sources: color movie film and an electronically generated horizon display. An approach, landing, and takeoff movie sequence filmed at Williams AFB projected on the visual display tracks student pilot control inputs. Changes in aircraft speed are achieved by changes in film speed; vertical and lateral deviations from the path of the film are produced by the EPT system. The EPT visual system provides: normal straight-in approach from 4 miles out, no flap, and simulated single engine configurations; touchdown, landing roll; and takeoff to 500 feet above ground level (AGL).

The electronically-produced visual scene showing a horizon defined by blue sky and a cloud deck is provided for airwork; horizontal translation is not provided. Display image motion capability of 360° continuous motion in pitch, roll, or heading permits acrobatic practice in the simulator; however, the limited motion cues and field of view detract from realism.

In addition to motion and visual cues, the T-4G includes a complete navigation/communication system and the capability to produce aural cues, such as wind, engine sound, landing gear warning, and system operations.

Aids for instruction included at both operator and instructor station are the capability to freeze the simulator during a mission and to reset to a preselected position within a matter of seconds.

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